Revised 08/16/99

INDIANA DEPARTMENT OF TRANSPORTATION
MATERIALS & TESTS DIVISION

# STRENGTH OF PORTLAND CEMENT CONCRETE PAVEMENT (PCCP) USING THE MATURITY METHOD ITM 402-99T

## 1.0 SCOPE

1.1 This test method covers the maturity concept as a non-destructive method to determine in-place concrete flexural strength in the field for opening of PCCP to traffic.

1.2 The values stated in either SI metric or acceptable English units are to be regarded separately as standard, as appropriate for a specification with which this ITM is used. Within the text, English units are shown in parenthesis. The values stated in each system may not be exact equivalents; therefore each system shall be used independently of the other, without combining values in any way.

1.3 This ITM may involve hazardous materials, operations, and equipment. This ITM does not purport to address all of the safety problems associated with the ITMs use. The ITM user's responsibility is to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2.0 REFERENCES

### 2.1 AASHTO STANDARDS

T 23, Making and Curing Concrete Test Specimens in the Field
T 97, Flexural Strength of Concrete
T 119, Slump of Hydraulic Cement Concrete
T 126, Making and Curing Concrete Test Specimens in the Laboratory
T 152, Air Content of Freshly Mixed Concrete by the Pressure Method
T 196, Air Content of Freshly Mixed Concrete by the Volumetric Method
M 241, Concrete Made by Volumetric Batching and Continuous Mixing

### 2.2 ASTM STANDARDS

E-574 Standard Specifications for Duplex Base Metal Thermocouple Wire with Glass Fiber or Silica Fiber Insulation

### 2.3 ITM STANDARDS

403, Water-Cementitious Ratio
802, Random Sampling
909, Verifying Thermometers

## 3.0 TERMINOLOGY

3.1 Terms and Abbreviations. Definitions for terms and abbreviations will be in accordance with 101, except as follows.

3.1.1 Equivalent Age. The time in days or hours at a specified temperature required to produce a flexural strength equal to the flexural strength achieved by a curing period at temperatures different from the specified temperature.

3.1.2 Maturity Function. A mathematical expression that uses the measured temperature history of a cementitious mixture during the curing period to calculate a maturity index that is indicative of the flexural strength at the end of that period.

3.1.3 Maturity Index. An indicator of flexural strength that is calculated from the temperature history of the cementitious mixture by using a maturity function.

3.1.4 Maturity Method. A technique for estimating concrete flexural strength that is based on the assumption that samples of a given concrete mixture attain equal flexural strengths if they attain equal maturity index values.

3.1.5 Maturity Curve. A curve established by plotting the flexural strength values vs time-temperature factor values.

3.1.6 Maturity-Strength Relationship. A relationship between the beam flexural strength and maturity index that is obtained by testing beam specimens whose temperature history up to the time of test has been recorded.

3.1.7 Time-Temperature Factor (TTF). TTF is a calculated value determined from time and temperature readings used to indicate the flexural strength of the concrete.

## 4.0 SIGNIFICANCE AND USE

4.1 This ITM shall be used to determine in-place flexural strength of concrete for opening of PCCP to traffic.

4.2 The hydration of cement and gain in strength of the concrete are dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as a function of time and temperature. This information may then be used to determine the strength of concrete without conducting destructive tests.

## 5.0 APPARATUS

5.1 Beam molds: Beam molds shall have the nominal dimensions of 150 mm x 150 mm x 500 mm (6 in. x 6 in. x 20 in.) in accordance with AASHTO T 23 and T 126.

5.2 Flexural Strength Testing Machine: A testing machine in accordance with AASHTO T 97 used to determine the flexural strength of concrete by breaking simply supported beams loaded at third points.

5.3 Maturity Meter: A device that automatically measures, computes and displays a time-temperature factor.

5.4 Hand-held Digital Thermometer: A verified thermometer having a thermocouple input connector and a power source. The minimum temperature measuring range shall be 0 °C to 66 °C (32 °F to 150 °F).

5.5 Type T Thermocouple Assembly: A Type T thermocouple assembly shall be two thermocouple elements having connection head and protecting tube in accordance with ASTM E 574. The coating from one end of the two thermocouple elements shall be stripped 13 mm (0.5 in.) and the ends twisted together to form a thermocouple assembly.

5.6 Concrete Mixing Equipment- The mixers shall be equipped with a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed concrete, discharge speed, and the weight-calibrated constant of the machine in terms of a revolution counter or other output indicator in accordance with AASHTO M 241. The capacity of the concrete mixer shall be large enough to place twelve beams at one time and to conduct all other tests.

## 6.0 GENERAL

6.1 This is a three step process.

6.1.1 Laboratory procedure in accordance with 7.0.
6.1.2 Field procedure in accordance with 8.0.

6.1.3 Validation procedure in accordance with 9.0.

6.2 The concrete shall be in accordance with 501.

6.3 An excel based spread sheet computer program furnished by the Department shall be used to calculate TTF and is based on the following equation.

$$\sum TTF = \sum [ ( ((T2 + T3)/2) + 10 ) ( A1- A2 )]$$

Where:

TTF, Time-Temperature Factor in ℃ x Hours
A1 - Age in hours
A2 - Previous age in hours
T2 - Concrete temperature in ℃ at measuring age
T3 - Previous temperature of concrete in ℃

7.0 LABORATORY PROCEDURE

7.1 Prior to construction a relationship between the TTF and the concrete flexural strength as measured by destructive methods through testing of beams shall be developed in the laboratory using project materials and the project concrete mix design.

7.2 Prepare concrete mixture and cast a minimum of twelve beams in accordance with AASHTO T 126. Tests for air content, slump and water-cementitious ratio shall be performed for each batch and recorded in accordance with AASHTO T 152, AASHTO T 119 and ITM 403 respectively.

7.3 A thermocouple assembly shall be inserted near each end of a test beam used to monitor temperature to the approximate mid-depth and such that they are approximately 75 mm (3 in.) from each side. This beam shall be designated temperature control beam. Secure the loose end of the assembly to the beam box to prevent being inadvertently pulled out of the beam during first 24 h of curing. This beam shall be the last beam to be tested for flexural strength.

7.4 The beams shall be covered with wet burlap and polyethylene sheeting upon initial set. The forms, wet burlap and polyethylene sheeting shall be removed after 24 h following casting. All beams shall be stored in a testing facility in accordance with 507.09, until each has been tested.

7.5 The TTF and flexural strength at four different ages shall be determined. Three specimens cast shall be tested for flexural strength in accordance with AASHTO T 97. The TTF shall be recorded directly by using maturity meter or calculated from a temperature reading by hand-held thermometer and at the same time the three specimens tested for flexural strength. The two readings for TTF shall be used in the development of the maturity curve. The first three beams shall be tested for flexural strength at 24 h after the casting. The remaining tests shall be spaced at 12 h intervals and span a range in flexural strength that includes the desired flexural strength.

7.5.1 When a maturity meter is used, the TTF values are computed by the meter and it shall remain connected to the temperature control beam until the test is completed.

7.5.2 When a hand-held thermometer is used, the measured temperature shall be recorded and entered in the spread sheet program to obtain values of TTF. An initial temperature of the first three beams shall be recorded at the time of casting. See ATTACHMENT I for a sample sheet.

7.6 The spread sheet program shall be used to determine maturity-strength relationship and maturity curve. The TTF number corresponding to the desired flexural strength shall be used to determine when the PCCP has reached opening flexural

strength. An example computer print out for Maturity-Strength Development is provided by ATTACHMENT II.

7.7 The influence of maturity on flexural strength of concrete is mix specific; therefore, a maturity-strength relationship and maturity curve established for one mix shall not be used for another mix.

7.8 The computed $R^2$ value obtained from regression analysis of the maturity-strength relationship shall be 0.95 or higher. The $R^2$ value can be found on the maturity curve chart. When $R^2$ value is below 0.95, the TTF value will not be generated. Therefore the trial batch is unacceptable, and a new trial batch will be required.

8.0 FIELD PROCEDURE

8.1 The tined concrete prior to curing shall be instrumented by inserting thermocouple assembly in to the plastic concrete.

8.2 A minimum of two thermocouple assemblies shall be placed within 30 m (100 ft.) of the end of each production day. Thermocouple assemblies shall be placed at random points determined in accordance with ITM 802 longitudinally along the PCCP. Thermocouple assembly shall not be placed within 1.5 m (5 ft) of transverse joint. The twisted end of thermocouple assembly shall be placed into the concrete until the end is at approximately the pavement mid-depth and 0.5 m (1.6 ft) from the edge of the plastic PCCP. Insertion may be accomplished by attaching the twisted end to a 6 mm (0.25 in.) diameter wooden dowel. The concrete shall be consolidated around the dowel. The portion of the dowel that protrudes above the PCCP shall be cut or broken off after the concrete is hardened.

8.3 The data may be collected by a maturity meter or a hand-held thermometer. When a maturity meter is used, the thermocouple assembly connector end shall be connected to a maturity meter in accordance with the manufacturer’s instructions. When a hand-held thermometer is used, the thermocouple assembly connector end is connected to the thermometer when a temperature is taken. An initial temperature of the concrete shall be taken immediately after the thermocouple assembly is inserted. An example for maturity data recording sheet is provided by ATTACHMENT I.

8.4 The PCCP may be opened to traffic when the calculated TTF reaches the required TTF corresponding to the desired flexural strength as determined in accordance with 7.0.

9.0 VALIDATION PROCEDURE

9.1 Field Validation tests shall be conducted on the third sublot of every fourth lot to determine if the concrete being produced is represented by the maturity curve.

9.1.1 A minimum of three additional beams shall be cast in accordance with AASHTO T 23 at the time of the QC air content test for sublot.

9.1.2 A thermocouple assembly shall be inserted near each end of a test beam used to monitor temperature to the approximate mid-depth and such that they are approximately 75 mm (3 in.) from each side. Insertion may be accomplished by attaching the twisted end to a 6 mm (0.25 in.) diameter wooden dowel. The concrete shall be consolidated around the dowel. This beam shall be designated temperature control beam. Secure the loose end of the assembly to the beam box to prevent being inadvertently pulled out of the beam during first 24-h of curing. This beam shall be the last beam to be tested for flexural strength.

9.1.3 The beams shall be covered with wet burlap and polyethylene sheeting upon initial set. The forms, wet burlap and polyethylene sheeting shall be removed after 24 h following casting. All beams shall be cured in a testing facility in accordance with 507.09, until each has been tested.

9.1.4 The TTF values of the three beams shall be monitored with a maturity meter in accordance with 7.5.1 or by temperature reading by hand-held thermometer in accordance with 7.5.2 until the TTF value reaches the required TTF value corresponding to the desired flexural strength. At the same time these three beams shall be tested for flexural strength in accordance with AASHTO T 97.

9.1.5 The average flexural strength of these three beams shall be compared against the desired flexural strength of PCCP. If the average of these tests is within 350 kPa (50 psi) of the original curve for the concrete mixture, the maturity curve is considered validated. If the average value is not within these limits, the maturity process is not valid. A computer printout example for validation of maturity curve is provided by ATTACHMENT III.

10.0 REPORT

10.1 Copies of all computer printouts, diskettes and field data shall be submitted to the Engineer upon completion of the work. All the wooden dowels and thermocouple assemblies shall be cutoff flush with the surface of the PCCP upon completion of the work.

ATTACHMENTS

Indiana Department of Transportation

# Maturity TestingTime Temperature Factor (TTF) Worksheet

Contractor: ABC CONSTRUCTION CO.

Project No.: R-99999 Curve No.: 3

Description: Date: 10/22/98

I-999 RECONSTRUCTION Time: 3:00 PM

Datum Temp: - 10 ° C

| Reading | | | | | |
|---|---|---|---|---|---|
| Number | Date / Time | Temperature | Age | TTF (C°-hrs) | Sum of TTF (C°-hrs) |
| 1 | 5/5/98 8:00 A | 28 ° C | | | |
| 2 | 5/6/98 8:00 A | 27 ° C | 24.0 hrs. | 900.0 | 900.0 |
| 3 | 5/7/98 8:00 A | 26 ° C | 48.0 hrs. | 876.0 | 1,776.0 |
| 4 | 5/8/98 8:00 A | 25 ° C | 72.0 hrs. | 852.0 | 2,628.0 |
| 5 | 5/9/98 2:30 P | 20 ° C | 102.5 hrs. | 991.3 | 3,619.3 |
| 6 | 5/10/98 3:30 A | 18 ° C | 115.5 hrs. | 377.0 | 3,996.3 |
| 7 | | | | | |
| 8 | | | | | |
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Signature

*Contractor Representative*

ITM 402-99T

Indiana Department of Transportation

Attachment II

# MATURITY TESTING - CURVE DEVELOPMENT

Contractor: ABC CONSTRUCTION CO.

Curve No.: 3

Contract No.: R-99999

Date: 05/05/99

Time: 1:48 PM

Location: I-999 RECONSTRUCTION

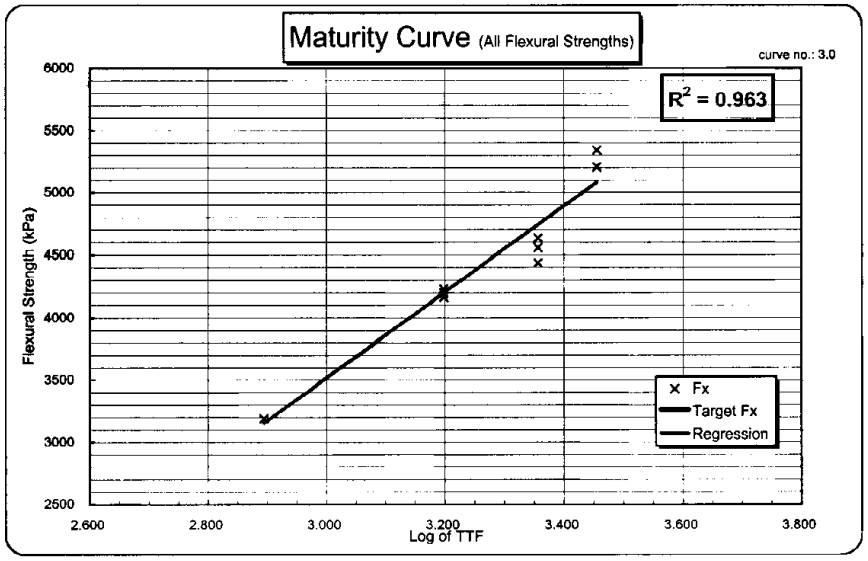
| Beam Number | Actual Load * (N) | Depth (mm) | Width (mm) | Flexural Coefficient | Flexural Strength (kPa) | Age at Break (hrs.) | Temperature-Time Factor | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Channel 1 (C°-hrs) | Channel 2 (C°-hrs) | Average TTF (C°-hrs) |
| 1 | 24,500 | 152 | 152 | 0.1301 | 3,188 | 24 | 784 | 784 | 784 |
| 2 | 24,500 | 152 | 152 | 0.1301 | 3,188 | 24 | 784 | 784 | 784 |
| 3 | 24,500 | 152 | 152 | 0.1301 | 3,188 | 24 | 784 | 784 | 784 |
| 4 | 32,000 | 152 | 152 | 0.1301 | 4,164 | 36 | 1,566 | 1,591 | 1,579 |
| 5 | 32,500 | 152 | 152 | 0.1301 | 4,229 | 36 | 1,566 | 1,591 | 1,579 |
| 6 | 32,250 | 152 | 152 | 0.1301 | 4,197 | 36 | 1,566 | 1,591 | 1,579 |
| 7 | 35,600 | 152 | 152 | 0.1301 | 4,633 | 48 | 2,262 | 2,285 | 2,274 |
| 8 | 35,000 | 152 | 152 | 0.1301 | 4,555 | 48 | 2,262 | 2,285 | 2,274 |
| 9 | 35,000 | 154 | 152 | 0.1268 | 4,437 | 48 | 2,262 | 2,285 | 2,274 |
| 10 | 40,000 | 152 | 152 | 0.1301 | 5,205 | 60 | 2,858 | 2,852 | 2,855 |
| 11 | 40,500 | 152 | 150 | 0.1319 | 5,341 | 60 | 2,858 | 2,852 | 2,855 |
| 12 | 40,000 | 152 | 152 | 0.1301 | 5,205 | 60 | 2,858 | 2,852 | 2,855 |

**Plastic Test Results**

| | |
|---|---|
| Test No: | P7 |
| Air Content: | 5.8% |
| Slump: | 51 mm |
| W/C Ratio: | 0.420 |

**Beam Monitoring**

| | |
|---|---|
| Equipment Used: | Maturity meter |
| Starting Temperature: | 20 ° C |




**Maturity Criteria for Opening Slab to Traffic**

(Equivelant to 3792kPa flexural beam strength)

| | |
|---|---|
| **TTF (C°-hrs)** | 1,203 |
| Log of TTF | 3.080 |

Mix No.: 54648

## Mix Ingredients

| Material | Type | Manufacturer / Plant |
|---|---|---|
| Cement | Type 1 | Gray Bros. Industries |
| Fly Ash | Type C | Just Ash |
| Coarse Agg. | #8 Stone | Stone World / (3rd St. Plant) |
| Fine Agg. | #23 Sand | Just In Time Sand Co. / (Red River) |

| Admixture | Type | Source | Dosage |
|---|---|---|---|
| Water Reducer | SLS 5500 | XL Chemical | 14.00 mL/m³ |
| A. E. Agent | SOP2500 | XL Chemical | 14.00 mL/m³ |

Comments:

Signature

*Contractor Representative*

ITM 402-99T

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Attachment III

# MATURITY TESTING - CURVE VALIDATION

Contractor: ABC CONSTRUCTION CO.

Curve No.: 3

Project No.: R-99999

Date: 05/10/99

Description: I-999 RECONSTRUCTION

Time: 8:09 AM

| Beam Number | Actual Load * (N) | Depth (mm) | Width (mm) | Flexural Coefficient | Flexural Strength (kPa) | Age at Break (hrs.) | Temperature-Time Factor: Channel 1 (C°-hrs) | Temperature-Time Factor: Channel 2 (C°-hrs) | Temperature-Time Factor: Average TTF (C°-hrs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 30,210 | 152 | 152 | 0.1301 | 3,931 | 36 | 1,275 | 1,275 | 1,275 |
| 2 | 30,200 | 152 | 152 | 0.1301 | 3,930 | 36 | 1,275 | 1,275 | 1,275 |
| 3 | 30,100 | 152 | 152 | 0.1301 | 3,917 | 36 | 1,275 | 1,275 | 1,275 |
| | | | | Average | 3,926 kPa | | | Average | 1275 |
| | | | | | | | | Log | 3.106 |

**Plastic Test Results**

Test No: P71

Air Content: 6.0%

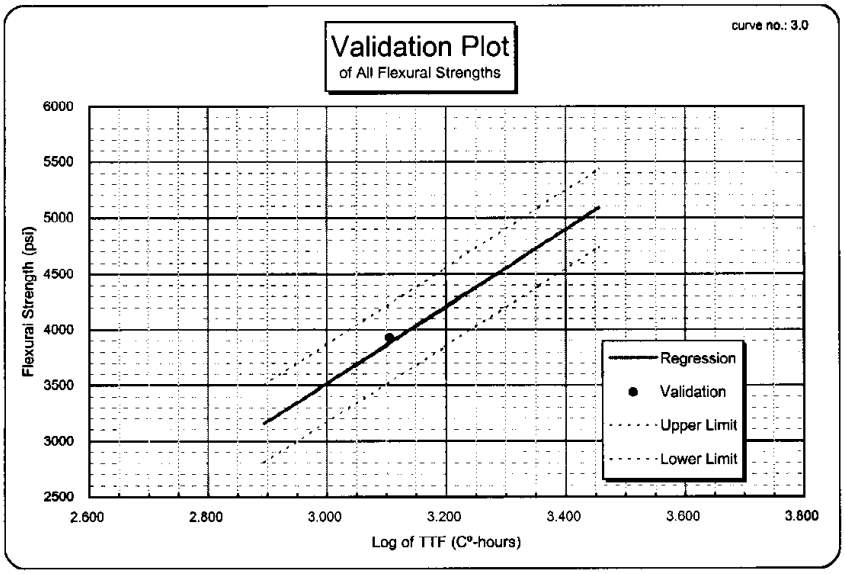
Slump: 2 in.

W/C Ratio: 0.396

**Beam Monitoring**

Equipment Used: Digital thermometer

Starting Temperature: 22 ° C




## Summary

| Predicted Beam Break* | | Actual Beam Breaks (average) | Difference from Target | Result |
|---|---|---|---|---|
| Lower Limit | 3,529 kPa | | | |
| Target | 3,879 kPa | 3,926 kPa | 47 kPa above | Within Acceptable Range |
| Upper Limit | 4,229 kPa | | | |

* Predicted beam break results were obtained by plotting the validation TTF on the mix maturity curve (above). Upper and lower limits are as specified for the test method.

Comments:

Signature

*Contractor Representative*